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## Segment Analysis of Johnson Creek: The Location of Sources of Pollution

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# **SEGMENT ANALYSIS OF Johnson Creek The Location of Sources of Pollution**

**Part of the Lake Ontario Watershed  
Located in Niagara County, NY**



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## SUMMARY

Johnson Creek is located in the southern portion of the Lake Ontario watershed, Orleans and Niagara Counties, New York. The relatively large watershed encompasses 98.6 square miles and flows into Lake Ontario near Kuckville, New York. Two years of continuous water quality monitoring indicated that the Johnson Creek watershed was a source of phosphorus, nitrate, organic nitrogen, sodium and soils to Lake Ontario. That is, Johnson Creek and the watershed it drained are a source of nutrients and soil pollution to Lake Ontario relative to other watersheds of similar size in western New York.

Where are the sources of nutrients, soils and salts within the Johnson Creek watershed? To answer this question the Soil and Water Conservation Districts of Niagara and Orleans Counties, along with the Center of Applied Aquatic Science and Aquaculture at SUNY Brockport, undertook the process of identifying the point and non-point sources of nutrients and soils by stressed stream analysis or segment analysis. With this report, we provide evidence suggesting the location and the intensity of pollution sources in the Johnson Creek watershed. We have identified three areas/sources in the Johnson Creek watershed that have consistently had high levels of nutrients, soils or sodium. What follows is a synopsis of what pollutants are being lost and where the sources are located. Maps are included in the narrative to locate these sites.

1. **There are three major areas of the Niagara County portion of Johnson Creek that are sources of non-point source pollution.** The three sites are N3, N9 and N21. The N3 series is the portion (~3 miles) of Johnson Creek that is between Site N3 on Carmen Road and Johnson Creek Road (Site N4). Site N9 is located just west of Route 148 (Quaker Rd), north of Hartland (~3 mile section). The N21 series is located south of Middleport and stretches for approximately two miles from Freeman Road (Site N21) to Griswold Road (Site N22). A series of additional samples were taken in each reach of the identified Sites to further pinpoint the sources.
2. **The N3 Series.** There were three areas of the N3 series that showed increases of greater than 100% from upstream sites to downstream sites indicating that they were sources of nutrients or soil during some or all of the sampling periods. Figure 1 depicts a general overview of the source locations. The area between Sites N3C (Drum Road) and N4 contained sources of TP, nitrate, TKN and TSS. An extra station sampled in between these sites (N3D) revealed that a source of nitrate was in the upstream portion of that reach. TSS increased by 605% between Sites N3C and N3B on 25 February 2000. In

addition, increases of greater than 50% of TP and SRP were observed between Sites N3A (Rose Road) and N3.

3. **N9 Series:** Upstream of Site N9 the creek branches into three reaches that were sampled. Stressed Stream Analysis showed high values of nutrients and soil at Site N9, which is located after a confluence of four branches of Johnson Creek. Each branch was subsequently sampled to narrow down the location of the nutrient and soil loss. Figure 2 summarizes the identified reaches of Johnson Creek that are sources of soil and nutrients to Site N9. The northern branch had three areas that contained sources of nutrients and soil of greater than 100% increases from upstream sites to downstream sites. Working downstream to Site N9, the areas identified between Sites N9E and N9D were source(s) of nitrate and TSS. The area between Sites N9C and N9B was a source of TP and SRP; sources of TKN, TP, SRP and TSS were observed between Sites N9B and N9A. The eastern branch had a >100% increase of nitrate between Site N9I and Site N9K. This branch was not completely sampled due to inaccessibility, but high concentrations of TSS and nitrate were detected upstream of Site N9I (depicted as red shading on Figure 2). The branch sampled at Site N9F also contained sources of nutrients and soil during events sampled. Specifically, the area between Sites N9G and N9F was a source (greater than a 100% increase) of TP, SRP, nitrate, TKN and TSS and the area upstream of Site N9H had high concentrations of TP, SRP and TKN (depicted as red shading on Figure 2).
4. **N21 Series:** There was a single area in the N21 Series that had an increase of over 100% between sampling sites (Figure 3). In the small area of the watershed between Sites N21D and N21C, TSS increased 244% during the 25 February 2000 event. The area of the watershed upstream of N22 in the headwaters had sources of TP, SRP, nitrate and TKN (depicted in red shading in Figure 3).

## RECOMMENDATIONS

This is a predominately agricultural area and the sources reflect that. Agricultural practices should be reviewed in this area and appropriate Best Management Practices (BMP) should be implemented. A tour of the individual operations in the identified areas is warranted to address any agricultural practices that could be contributing nutrients and

soil to Johnson Creek. BMP's are discussed in detail below and should be implemented where they are warranted.

Agricultural Environmental Management (AEM) was developed by farmers, state, federal and local governments and farm conservation professionals to enhance the protection of important environmental resources, such as the state's rivers, lakes and streams, while maintaining a healthy agricultural economy. Agricultural land makes an important contribution to the economy, diversity and beauty of Niagara County. Agricultural Environmental Management calls for a tiered approach to implement Best Management Practices (BMPs) on watershed farms. The tiered approach begins with the farmer's self-assessment, followed by a technical assessment by program personnel and implementation

Identified point and non-point sources of nutrients and solids can be remediated using Best Management Practices (BMP). Whether or not management practices include a reduction of cropland or fertilization, control of water movement can be a means of significantly reducing non-point source pollution. Since water must come in contact with the nutrient source and then be transported to the surface (or subsurface) water body, the nutrients in water bodies are functions of soil fertility and quantities of transporting water. Management practices, which reduce surface runoff, have been shown to dramatically decrease the magnitudes of sediment and chemical losses from land areas.

## INTRODUCTION

Johnson Creek is located in the south portion of the Lake Ontario watershed, Orleans and Niagara Counties, New York (Fig. 1). The relatively large watershed encompasses 98.6 square miles and flows into Lake Ontario near Kuckville, New York. The Orleans County Soil and Water Conservation District has monitored Johnson Creek beginning in 1997 in collaboration with the State University of New York at Brockport's Center for Applied Aquatic Science and Aquaculture (CAASA). Two years of monitoring indicated that the Johnson Creek watershed was a source of phosphorus, nitrate, organic nitrogen, sodium and soils to Lake Ontario (1, 2). That is, Johnson Creek and the watershed it drained are sources of nutrients and soil pollution to Lake Ontario. The next question becomes where are the sources of nutrients, soils and salts within the Johnson Creek watershed? To accomplish this, the Soil and Water Conservation Districts of both Niagara and Orleans Counties jointly began a process called stressed stream analysis or segment analysis (3) in which point and non-point sources were identified. With this report, we provide evidence suggesting the location of pollution sources in the Niagara County portion of the Johnson Creek watershed. The Orleans County portion of the watershed was reported on in Makarewicz and Lewis (4).

Stressed stream analysis is an approach that identifies impacted subwatersheds and their associated streams (5,6,7,8,9). Within a watershed, stressed stream analysis is an approach for determining how and where a stream and its ecological community are adversely affected by a pollution source or other disturbances. Stressed stream analysis is an integrative, comprehensive approach for determining the environmental health of a watershed and its constituent streams. It is a technique that identifies the sources, extent, effects and severity of pollution in a watershed. In its fullest use, it combines elements of the sciences of hydrology, limnology, ecology, organismal biology and genetics in an integrated approach to analyze cause and effect relationships in disturbed stream ecosystems.

Within a subwatershed, the stream(s) is used to monitor the "health" of the watershed. Because nutrients are easily transported by water, they can be traced to their source by systematic geographic monitoring of the stream. Stressed stream analysis is a technique that divides the impacted subwatershed into small distinct geographical units. Samples are taken at the beginning and end of each unit of the stream to determine if a nutrient source occurs within that reach. At completion, the cause and extent of pollution have been identified. If

needed, the severity of the pollution within the impacted subwatershed and or the entire watershed can then be evaluated by spatial analysis of the quantity and quality of biological indicators, such as fish and invertebrates, and by biological examination of structural and functional changes in individual organisms and populations in affected communities. Once identified, sources may be corrected using "Best Management Practices" (BMP).

## **DEFINITIONS**

Total Phosphorus- A measure of all forms of the element phosphorus. Phosphorus is an element required for plant growth on land or in water. In lakes, phosphorus is often the limiting factor of phytoplankton growth and is the cause of eutrophication, or overproduction, of lakes. Phosphorus may enter a watershed in soluble or organic form from several sources including sewage, heavy-duty detergents, fertilizer and agricultural waste. Some forms of phosphorus are more available to, and cause more immediate activity in, plants.

Soluble Reactive Phosphorus- A measure of the most available and active form of phosphorus.

Nitrate + Nitrite- A measure of the soluble forms of nitrogen used readily by plants for growth. Sources of nitrates in the environment are many and include barnyard waste and fertilizer.

Total Kjeldahl Nitrogen- The Kjeldahl method is a convenient method of analysis for nitrogen but cannot be used for all types of nitrogen compounds. It is, however, a good measure of organic nitrogen, including ammonia. Manure, for example, contains a large amount of organic nitrogen.

Sodium- A measure of the mineral, most commonly found as sodium chloride (NaCl), dissolved in water. NaCl naturally occurs in deep layers of local bedrock. Mined, it is stored and spread as a de-icing agent on roads and other pavements.

Total Suspended Solids - A measure of the loss of soil and other materials suspended in the water from a watershed. Water-borne sediments act as an indicator, facilitator and agent of pollution. As an indicator, they add color to the water. As a facilitator, sediments often carry other pollutants, such as nutrients and toxic substances. As an agent, sediments smother



organisms and clog pore spaces used by some species for spawning.

## SAMPLING AND ANALYTICAL METHODS

Segment analysis was performed on six dates on the Niagara County portion of Johnson Creek. The watershed was sampled on 21 May 1998 during baseline (non-event) stream conditions. The subsequent segment analyses were performed during event conditions (8 July 1998, 24 January 1999, 4 January 2000, 25 February 2000 and 31 January 2001). All samples (total of 125 samples) were analyzed for nitrate, soluble reactive phosphorus, total phosphorus, total Kjeldahl nitrogen, sodium and total suspended solids.

Specific locations of all sampling sites are shown in Figures 1 to 3.

All sampling bottles were pre-coded so as to ensure exact identification of the particular sample and were routinely cleaned with phosphate free RBS between sampling dates. Containers were rinsed prior to sample collection with the water being collected. In general, all procedures followed EPA standard methods (10) or Standard Methods for the Analysis of Water and Wastewater (11). Sample water for dissolved nutrient analyses (SRP, nitrate + nitrite) was filtered immediately with 0.45- $\mu$ m MCI Magna Nylon 66 membrane and either frozen or analyzed within 48 hours of collection.

**Nitrate+Nitrite:** Dissolved nitrate+nitrite nitrogen analyses were performed by the automated (Technicon autoanalyser) cadmium reduction method (11).

**Soluble Reactive Phosphorus:** Sample water was filtered through a 0.45- $\mu$ m membrane filter. The filtrate was analyzed for orthophosphate using the automated (Technicon) colorimetric ascorbic acid method (11). The formation of the phosphomolybdenum blue complex was read colorimetrically at 880nm.

**Total Phosphorus:** The persulfate digestion procedure was used prior to analysis by the automated (Technicon autoanalyser) colorimetric ascorbic acid method (11).

**Total Kjeldahl Nitrogen:** Analysis was performed using a modification of the Technicon Industrial Method 329-74W/B. The following modifications were made:

- In the sodium salicylate-sodium nitroprusside solution, sodium nitroprusside was increased to 0.4 gm/L.
- The reservoir of the autoanalyser was filled with 2M H<sub>2</sub>SO<sub>4</sub> instead of distilled water.
- Other reagents were made fresh prior to analysis.

**Sodium:** Sodium analysis was performed by Atomic Absorption Spectrophotometry (11).

**Total Suspended Solids:** APHA (11) Method 2540D was employed for this analysis.

## QUALITY CONTROL

The Water Chemistry Laboratory at SUNY Brockport is State and Nationally certified through the New York State Department of Health's Environmental Laboratory Approval Program (ELAP - # 11439) and the National Environmental Laboratory Accreditation Conference (EPA Lab Code NY 01449). These programs include bi-annual proficiency audits, annual inspections and good laboratory practices documentation of all samples, reagents and equipment (Table 1).

## RESULTS

### *Chronological Account of Stressed Stream Analysis:*

#### *21 May 1998 (Figure 4)*

The initial sampling event occurred during baseline conditions. The purpose behind this sampling was to initiate the program and to determine the variability of nutrient concentrations along sections of Johnson Creek during a period of no precipitation or “non-event” period. Eighteen stations were sampled in the Johnson Creek watershed and results are presented in Table 2 and Figure 1. Although the results presented represent baseline conditions, several potential sources of nutrient loss from the watershed were identified. At Stations N3, N4 and N5 elevated total phosphorus (TP), total Kjeldahl nitrogen (TKN) concentrations were observed with the source upstream of Station N5. At Station N6 a high concentration of TKN was observed; the source was between Stations N6 and N7. High concentrations of both TP and TKN were observed at Station 8.

Samples were taken above and below the sewage treatment plant (STP) in Middleport. The soluble and total phosphorus concentrations were more than twice as high below the STP versus above the plant. Although several areas of concern were identified, it was decided to sample all stations during the next hydrometeorological event (i.e., rain event).

#### *8 July 1998 (Figure 5)*

During a moderate precipitation (0.48 inches) event on 8 July 1998, 19 stations were sampled on Johnson Creek. As expected, concentrations of all nutrients were generally much higher in

the creek than during baseline conditions. With rainfall, water runs over the landscape carrying soil and nutrients that dissolve in the water.

From Site N4 downstream to Site N3, SRP increased 487%, TP increased 628%, TSS increased 256% and TKN increased 266%. Site N21 was relatively high in TP (1,327 µg P/L) and TKN (4,620 µg N/L) when compared to other locations sampled during this event. Organic nutrients were also high in the vicinity of the sewage treatment plant in Middleport.

### ***24 January 1999 (Figure 6)***

Twenty-one stations were sampled on 24 January 1999. The Niagara County portion of Johnson Creek was narrowed down to three areas that were identified as having significant losses of nutrients and soil to the creek. There was a source of TP (89% increase), SRP (63% increase), TKN (200% increase), TSS (>10,000% increase), sodium (127% increase) and nitrate (136% increase) between Sites N3 and N4. Upstream of Site N9, there are sources of TP (1312 µg P/L), SRP (955 µg P/L), nitrate (6.2 mg N/L) and TKN (3420 µg N/L). The reach between Sites N21 and N22 contained a source of TP, SRP, nitrate and TKN as all of these parameters increased over 49% between the two sites. These areas will be subject of subsequent stressed stream sampling efforts to further pinpoint the sources of pollution in Johnson Creek.

### ***4 January 2000 Event***

#### **N3 Series (Figures 7-12):**

The N3 series begin at Site N3 on Carmen Road and moves upstream to Johnson Creek Road (Site N4). Four samples were taken in this reach of the creek on 4 January 2000. A major loss of nutrients and soil occurred between Sites N3C and N4. This suggests that the source is related to erosive forces of the runoff water and may be organic in nature.

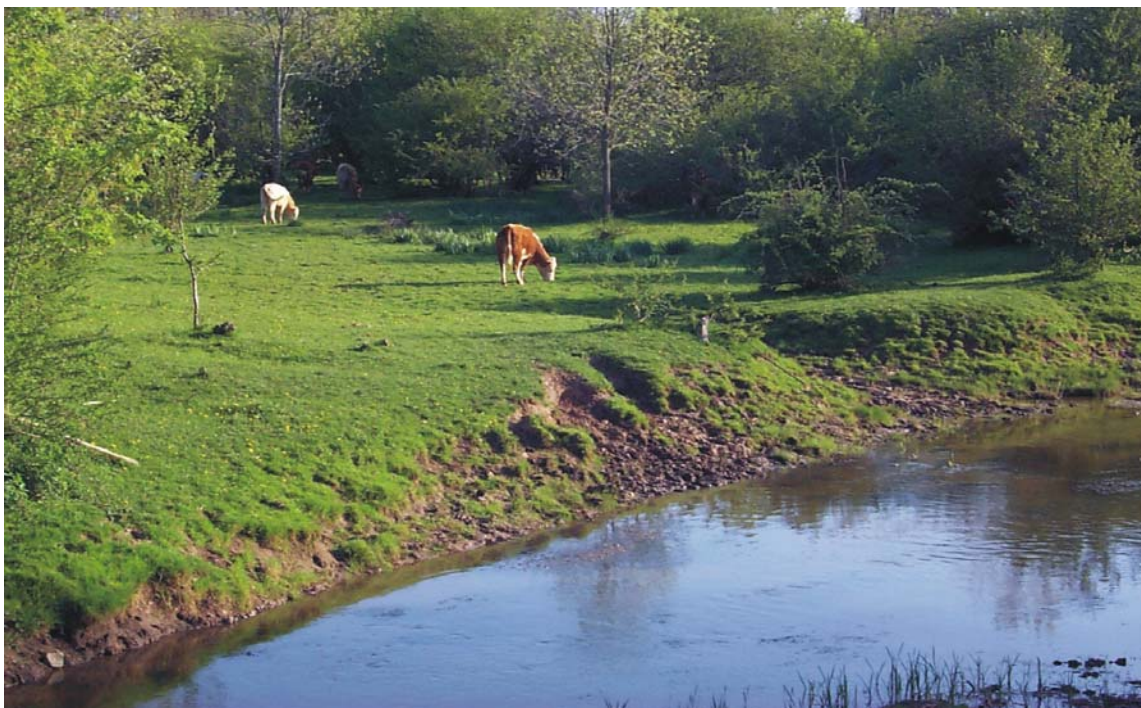
A source of phosphorus exists between Site N3C (Drum Road) and Site N4 (Johnson Creek Road). Total phosphorus increased five fold from 105.3 µg P/L at Site N4 to 589.5 µg P/L at Site N3C. Similarly, SRP doubled between the same two sites. Nitrate doubled and TKN increased by a factor of five between Sites N3C and N4. TSS increased five fold from 4.0

mg/L at Site N4 to 22.2 mg/L at Site N3C. There were no significant sources of sodium to Johnson Creek during the 4 January 2000 event in the N3 series of sampling sites.

**N9 Series (Figures 13-18):**

Site N9 is located just west of Route 148 (Quaker Rd), north of Hartland (Figure 2).

Upstream of Site N9 the creek branches into three reaches that were sampled on 4 January 2000. The northern-most branch was sampled at Site N9A on Chapman Road and contained the highest concentrations of SRP, TP, sodium, TSS and TKN in this series. This branch was sampled further at Sites N9B, N9D and N9E upstream on Site N9A. Analysis of these samples revealed that the source of pollution observed at Site N9A was between N9B on Hartland Road and N9A on Chapman Road.



**Johnson Creek at Drum Road**

Nitrate concentrations were high at Site N9 (4.95 mg N/L). The sources appeared to be in the two other branches of the N9 series, especially the southernmost branch (Figure 2). The southernmost branch was sampled at Site N9K and had a nitrate concentration of 8.70 mg N/L. The middle branch contained a source of nitrate between sites N9G (1.65 mg N/L) and

N9F (4.95 mg N/L), which also contributed to the high nitrate concentration measures at Site N9. There was also a source of TKN in that same reach of the stream (N9G; 850 µg/L to N9F; 1100 µg N/L).

#### **N21 Series (Figures 19-24):**

The N21 series is located south of Middleport and stretches from Freeman Road (Site N21) to Griswold Road (Site N22) (Figure 3). Most parameters were relatively constant throughout this reach with the following exceptions. There was an increase of soluble reactive phosphorus and nitrate between Sites N21D and N21C. There was also an increase of SRP and TKN between N21A and N21. Total suspended solids were relatively high (~30 mg/L) for this event throughout the whole series.

### ***25 February 2000 Event***

#### **N3 Series (Figures 7-12):**

The previous event identified sources in the area between Sites N3C and N4. An additional intermediate site was added in this area (N3D) for this event. In general, there was a steady increase in the concentrations of nutrients and soil from Site N4 through Site N3D to Site N3C. However, there was not the dramatic increase in concentration that was observed in this reach during the event on 4 January 2000. There were larger increases in TP (199 to 247 µg P/L), TSS (17 to 119 mg/L) and TKN (1010 to 1390 µg N/L) from Site N3C to Site N3B, respectively.

#### **N9 Series (Figures 13-18):**

The N9 series had the higher concentrations of phosphorus, nitrate and TKN than the N3 or N21 series monitored during this event. There were sources of nutrients in the area between Sites N9C and N9B. Phosphorus concentrations doubled and TKN increased from 860 to 1350 µg N/L between these sites. Nitrate was over 3 mg N/L at Sites N9, N9F and N9K. Nitrate increased 1.5 times between Sites N9G and N9F, while no source identification could be made upstream of Site N9K due to lack of landowner permission for additional sampling. The area between Sites N9G and N9F was also a source of TP (78 to 300 µg P/L), SRP (81 to

463  $\mu\text{g P/L}$ ) and TKN (560 to 1480  $\mu\text{g N/L}$ ). Site N9K was also relatively high in SRP, TP nitrate and TKN.

#### **N21 Series (Figures 19-24):**

The highest concentrations of phosphorus and nitrate occurred at the downstream end of this series (Site N21). The sources appeared to be in the area between Site N21A and N21. The highest concentration of TSS and TKN was in the upstream part of the series (Sites N22, N21F and N21E).

### ***31 January 2001 Event***

#### **N3 Series (Figures 7-12):**

There were three detected phosphorus sources in the N3 series on 21 January. In the reach between Sites N4 and N3D, TP increased from 164 to 209  $\mu\text{g P/L}$ , while SRP increased from 151 to 209  $\mu\text{g P/L}$ . The source in this area was inorganic in nature in that the soluble fraction of phosphorus represents over 90% of the total phosphorus observed at these locations.

There were also increases in phosphorus concentrations observed between Sites N3C and N3B as well as a substantial increase between sites N3A and N3.

Nitrate concentrations doubled between Sites N4 and N3D. TKN increased from 670 to 1290  $\mu\text{g N/L}$  from Site N4 to Site N3D, respectively. TKN also increased in the section of Johnson Creek between Site N2B through N3A to Site N3.

#### **N9 Series (Figures 13-18):**

A source of soluble inorganic phosphorus (99% of the total phosphorus was in the soluble form) was detected between Sites N9C and N9B. Soluble phosphorus was also relatively high upstream of Site N9H. Soluble nutrients in high concentrations may be caused by the spreading of inorganic fertilizer on agricultural fields.

There were four stretches of Johnson Creek that lost significant amounts of nitrate. Nitrate concentrations doubled between Sites N9G and N9F as well as between Sites N9I and N9K. Nitrate nearly doubled between Site N9E and N9D and increased a full milligram per liter from Site N9C to Site N9B.

Total suspended solids were generally low in this series ( $< 6$  mg/L), except in the branch containing Sites N9K (18 mg/L) and N9I (35 mg/L).

On 31 January 2001, TKN concentrations were highest at N9A. TKN increased along that branch from N9C (680  $\mu\text{g N/L}$ ) to N9B (880  $\mu\text{g N/L}$ ) to N9A (1020  $\mu\text{g N/L}$ ).

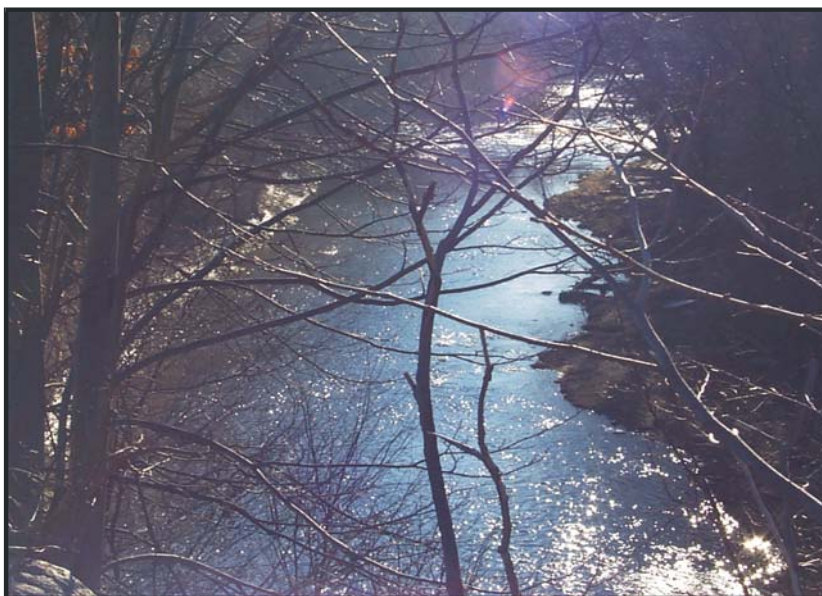
#### **N21 Series (Figures 19-24):**

Nitrate increased from 0.95 mg N/L to 1.22 mg N/L between Sites N22 and N21F. Similarly, the nitrate concentrations increased from 0.95 to 1.53 mg N/L from Site N21A to N21.

## **DISCUSSION**

The quality and quantity of runoff from a watershed into a stream are ultimately influenced by people. The amount of runoff is determined by the amount of excess precipitation, that which neither sinks into the ground nor is stored at the surface. Precipitation excess is

### **Johnson Creek Near Kuckville**



### **Johnson Creek near Kuckville**

determined primarily by climate, vegetation, infiltration capacity, surface storage and land use by people (1, 2). Impervious landscapes (e.g., parking lots), removal of wetlands

and vegetation in general, storm sewers, blockage of streams by debris, etc., all contribute to rapid rises in stream level and potential flooding.

Similarly, land usage

contributes to the quality of the water in the stream and ultimately Lake Ontario. For example, deicing salt spread on roads is easily dissolved and accumulates in streams raising the concentration of sodium in water. Another example is the spreading of manure on the land. If done properly, this can be a reasonable practice enriching the soil. If not, the result may be elevated levels of fecal coliform bacteria and increased levels of phosphorus, organic

nitrogen and nitrates that cause health concerns or cause eutrophication of downstream systems. Land use practices initiated by people can and do affect stream water quality and stream discharge. If we can identify the sources of pollution, remedial action plans and best management plans can be initiated that mitigate downstream and lake effects.

### ***Major Sources of Sodium (Deicing salt) in the Johnson Creek Watershed***

Environmental concerns revolving around elevated levels of deicing salt include: damage to vegetation, affect fish spawning in streams, pollute ground water making well water undrinkable, disintegrate pavement and cause metal corrosion. Elevated levels of sodium (>150 mg Na/L) were not observed at any sites in the Niagara County portion of Johnson Creek during the study period.

### ***Summary of Sources of Nutrients and Soil in Johnson Creek***

1. **There are three major areas of the Niagara County portion of Johnson Creek that are sources of non-point source pollution.** The three sites are N3, N9 and N21. The N3 series is the portion (~3 miles) of Johnson Creek that is between Site N3 on Carmen Road and Johnson Creek Road (Site N4). Site N9 is located just west of Route 148 (Quaker Rd), north of Hartland (~3 mile section). The N21 series is located south of Middleport and stretches for approximately 2miles from Freeman Road (Site N21) to Griswold Road (Site N22). A series of additional samples were taken in each reach of the identified Sites to further pinpoint the sources.
2. **The N3 Series.** There were three areas of the N3 series that showed increases of greater than 100% from upstream sites to downstream sites. This increase indicates that they were sources of nutrients or soil during some or all of the sampling periods. Figure 1 depicts a general overview of the source locations. The area between Sites N3C (Drum Road) and N4 contained sources of TP, nitrate, TKN and TSS. An extra station sampled in between these sites (N3D) revealed that a source of nitrate was in the upstream portion of that reach. TSS increased by 605% between Sites N3C and N3B on 25 February 2000. In addition, increases of greater than 50% of TP and SRP were observed between Sites N3A (Rose Road) and N3.



3. **N9 Series:** Upstream of Site N9 the creek branches into three reaches that were sampled. Stressed Stream Analysis showed high values of nutrients and soil at Site N9, which is located after a confluence of four branches of Johnson Creek. Each branch was subsequently sampled to narrow down the location of the nutrient and soil loss. Figure 2 summarizes the identified reaches of Johnson Creek that are sources of soil and nutrients to Site N9. The northern branch had three areas that contained sources of nutrients and soil indicated by increases greater than 100% from upstream sites to downstream sites. Working downstream to Site N9, the area between Sites N9E and N9D was a source(s) of nitrate and TSS. The area between Sites N9C and N9B was a source of TP and SRP; sources of TKN, TP, SRP and TSS were observed between Sites N9B and N9A. The eastern branch had a >100% increase of nitrate between Site N9I and Site N9K. This branch was not completely sampled due to inaccessibility, but high concentrations of TSS and nitrate were detected upstream of Site N9I (depicted as red shading on Figure 2). The branch sampled at Site N9F also contained sources of nutrients and soil during events sampled. Specifically, the area between Sites N9G and N9F was a source (greater than a 100% increase) of TP, SRP, nitrate, TKN and TSS and the area upstream of Site N9H had high concentrations of TP, SRP and TKN (depicted as red shading on Figure 2).
4. **N21 Series:** There was a single area in the N21 Series that had an increase of over 100% between sampling sites (Figure 3). In the small area of the watershed between Sites N21D and N21C, TSS increased 244% during the 25 February 2000 event. The area of the watershed upstream of N22 in the headwaters had sources of TP, SRP nitrate and TKN (depicted in red shading in Figure 3).

## RECOMMENDATIONS

This is a predominately agricultural area and the sources reflect that. Agricultural practices should be reviewed in this area and appropriate Best Management Practices (BMP) should be implemented. A tour of the individual operations in the identified areas is warranted to address any agricultural practices that could be contributing nutrients and soil to Johnson Creek. BMP's are discussed in detail below and should be implemented where they are warranted.

### **Agricultural Environmental Management and Best Management Practices:**

Agricultural Environmental Management (AEM) was developed by farmers, state, federal and local governments and farm conservation professionals to enhance the protection of important environmental resources, such as the state's rivers, lakes and streams, while maintaining a healthy agricultural economy. Agricultural land makes an important contribution to the economy, diversity and beauty of Niagara County. Agricultural Environmental Management calls for a tiered approach to implement Best Management Practices (BMPs) on watershed farms. The tiered approach begins with the farmer's self-assessment, followed by a technical assessment by program personnel and implementation

Identified point and non-point sources of nutrients and solids can be remediated using Best Management Practices (BMP). Whether or not management practices include a reduction of cropland or fertilization, control of water movement can be a means of significantly reducing non-point source pollution. Since water must come in contact with the nutrient source and then be transported to the surface (or subsurface) water body, the nutrients in water bodies are functions of soil fertility and quantities of transporting water. Management practices, which reduce surface runoff, have been shown to dramatically decrease the magnitudes of sediment and chemical losses from land areas (9).

**Agriculture:** Haith (9) and the NYSDEC (10) recommend use of buffer strips of forest or grass between the pollutant source and a stream to intercept the runoff, resulting in removal by deposition or filtering by the vegetative cover. Other cropland management practices include diversions, terraces contour cropping, strip cropping, waterways, minimum and no tillage. Livestock operation controls include barnyard runoff management, manure storage facilities and livestock exclusion from stream banks. They may also include structural devices such as grassed waterways, sediment retention basins, erosion control weirs and animal waste holding tanks. BMP's are designed to reduce sediment and nutrient transport to streams and lakes. They may benefit the farmer in the long term by decreasing fuel and fertilizer costs and by improving soil productivity. Furthermore, the advent of Concentrated Animal and Feed Operations (CAFO) permits, regulatory control of farms with large numbers of animals may be inevitable.

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Table 1. Results of the semi-annual New York State Environmental Laboratory Assurance Program (ELAP Lab # 11439, SUNY Brockport) Non-Potable Water Chemistry Proficiency Test, July 1999. Score Definition: 4 (Highest) = Satisfactory, 3 = Marginal, 2 = Poor, 1 = Unsatisfactory.

Analyte	Mean/Target	Result	Score
Residue			
Solids, Total Suspended	18.3 mg/L	18.2 mg/L	4
Hydrogen Ion (pH)			
Hydrogen Ion (pH)	6.00	5.96	4
Organic Nutrients			
Kjeldahl Nitrogen, Total	14.70 mg/L	15.60 mg/L	4
Phosphorus, Total	1.56 mg/L	1.59 mg/L	4
Total Alkalinity			
Alkalinity	94.60 mg CaCO <sub>3</sub> /L	98.32 mg CaCO <sub>3</sub> /L	4
Inorganic Nutrients			
Nitrate (as N)	14.80 mg/L as N	13.33 mg/L as N	4
Orthophosphate (as P)	0.914 mg/L as P	0.920 mg/L as P	4
Minerals			
Chloride	180.0 mg/L	183.2 mg/L	4
Wastewater Metals I and II			
Calcium, Total	20.30 mg/L	19.54 mg/L	4
Magnesium, Total	13.00 mg/L	14.22 mg/L	4
Potassium, Total	5.03 mg/L	5.29 mg/L	4
Sodium, Total	35.70 mg/L	36.68 mg/L	4

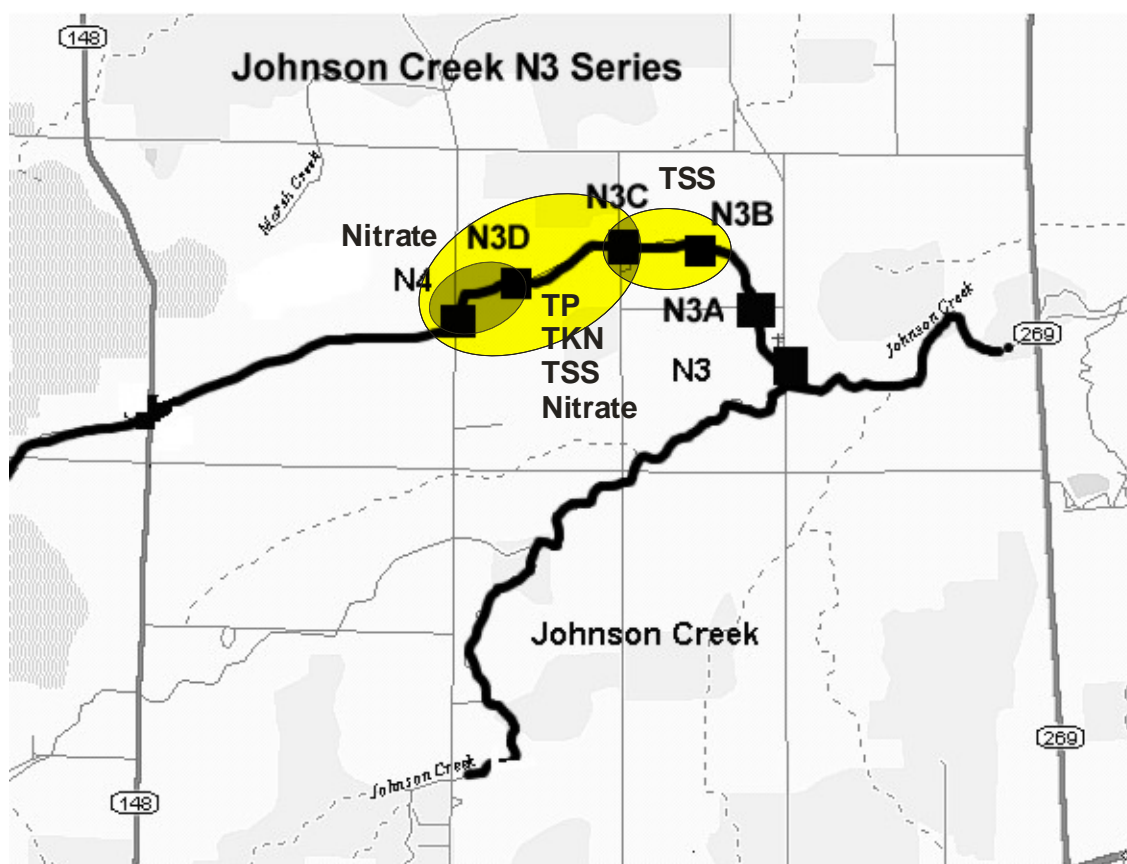


Figure 1. Summary of identified sources of pollution for the N3 series of sites on Johnson Creek. The yellow shaded areas indicate increases of 100% or more between sites during one or more of the Stressed Stream Analyses.

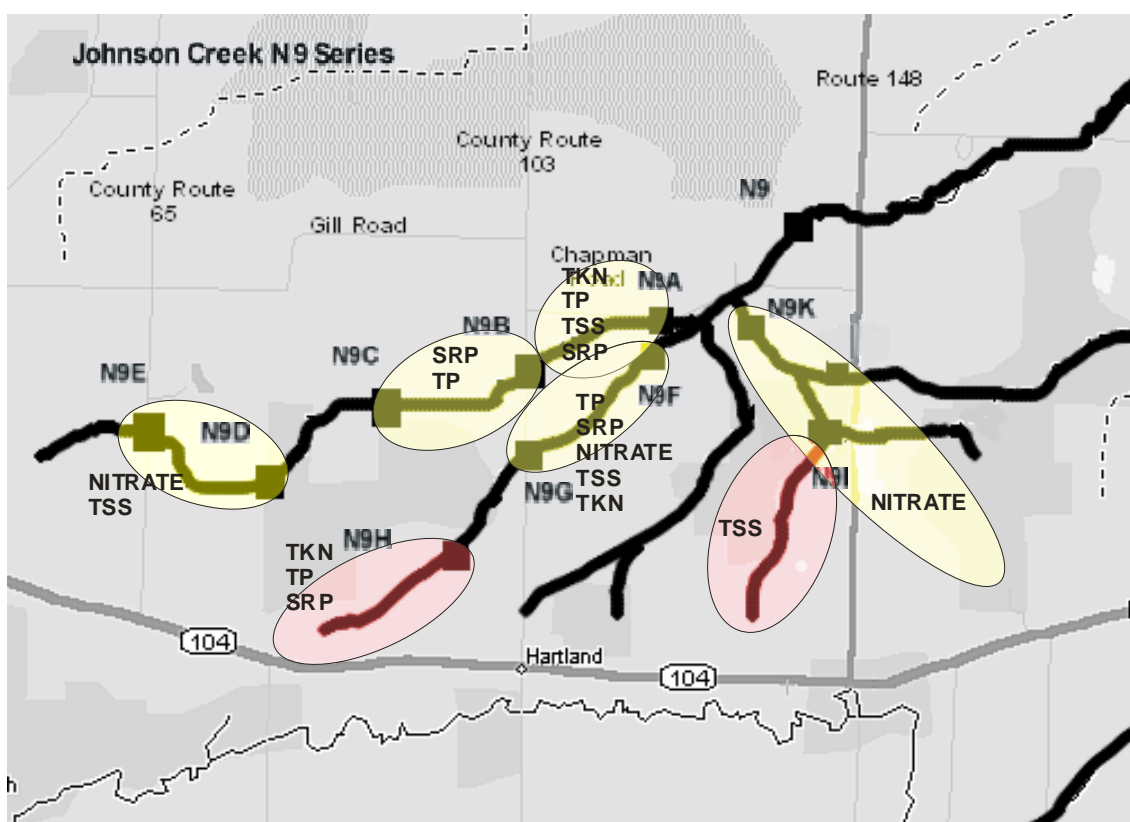


Figure 2. Summary of identified sources of pollution for the N9 series of sites on Johnson Creek. The yellow shaded areas indicate increases of 100% or more between sites during one or more of the Stressed Stream Analyses. The red shaded areas indicate headwater areas that have relatively high concentrations of the indicated parameters.

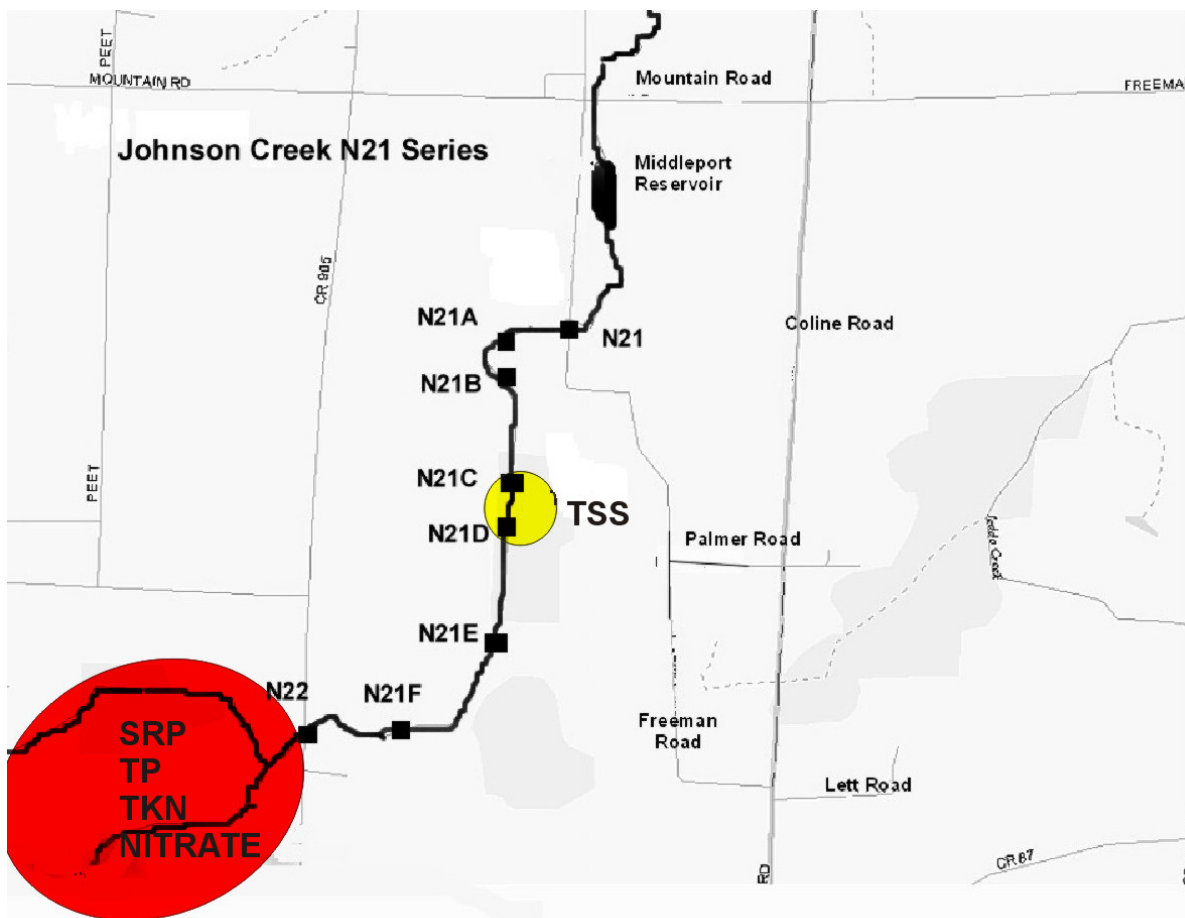


Figure 3. Summary of identified sources of pollution for the N21 series of sites on Johnson Creek. The yellow shaded areas indicate increases of 100% or more between sites during one or more of the Stressed Stream Analyses. The red shaded areas indicate headwater areas that have relatively high concentrations of the indicated parameters.

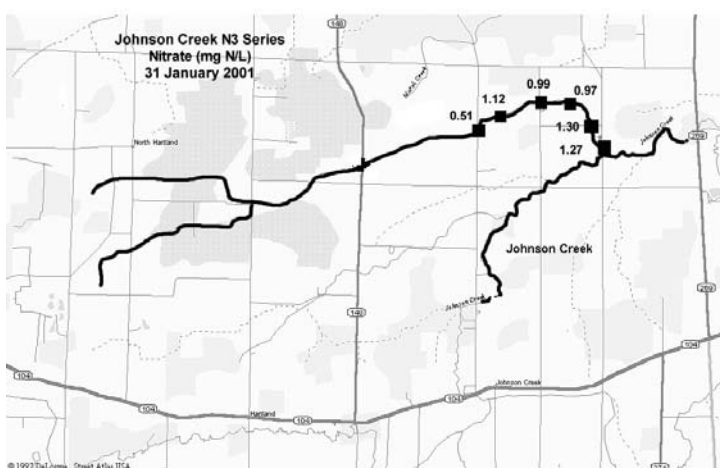
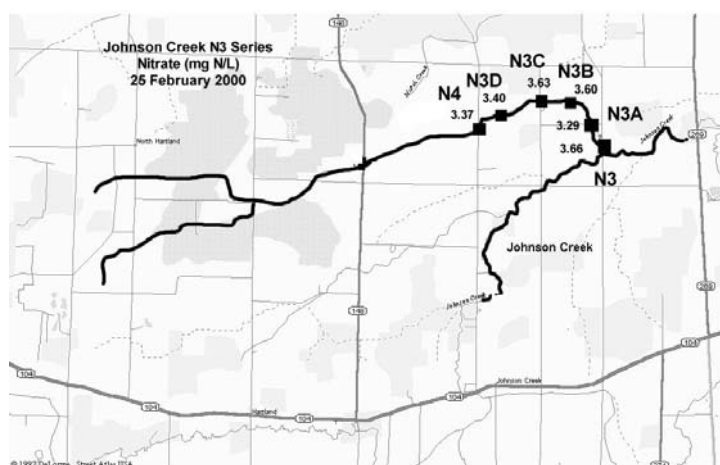
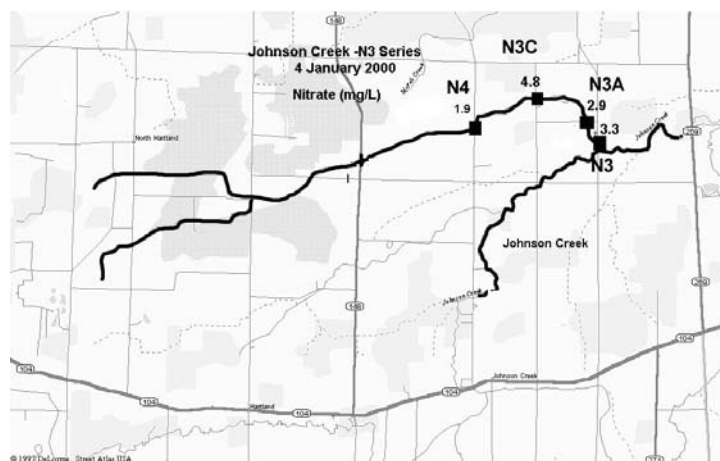


Figure 7. Nitrate results for the N3 series of sites on Johnson Creek for the sampling dates 4 January 2000, 25 February 2000, and 31 January 2001.







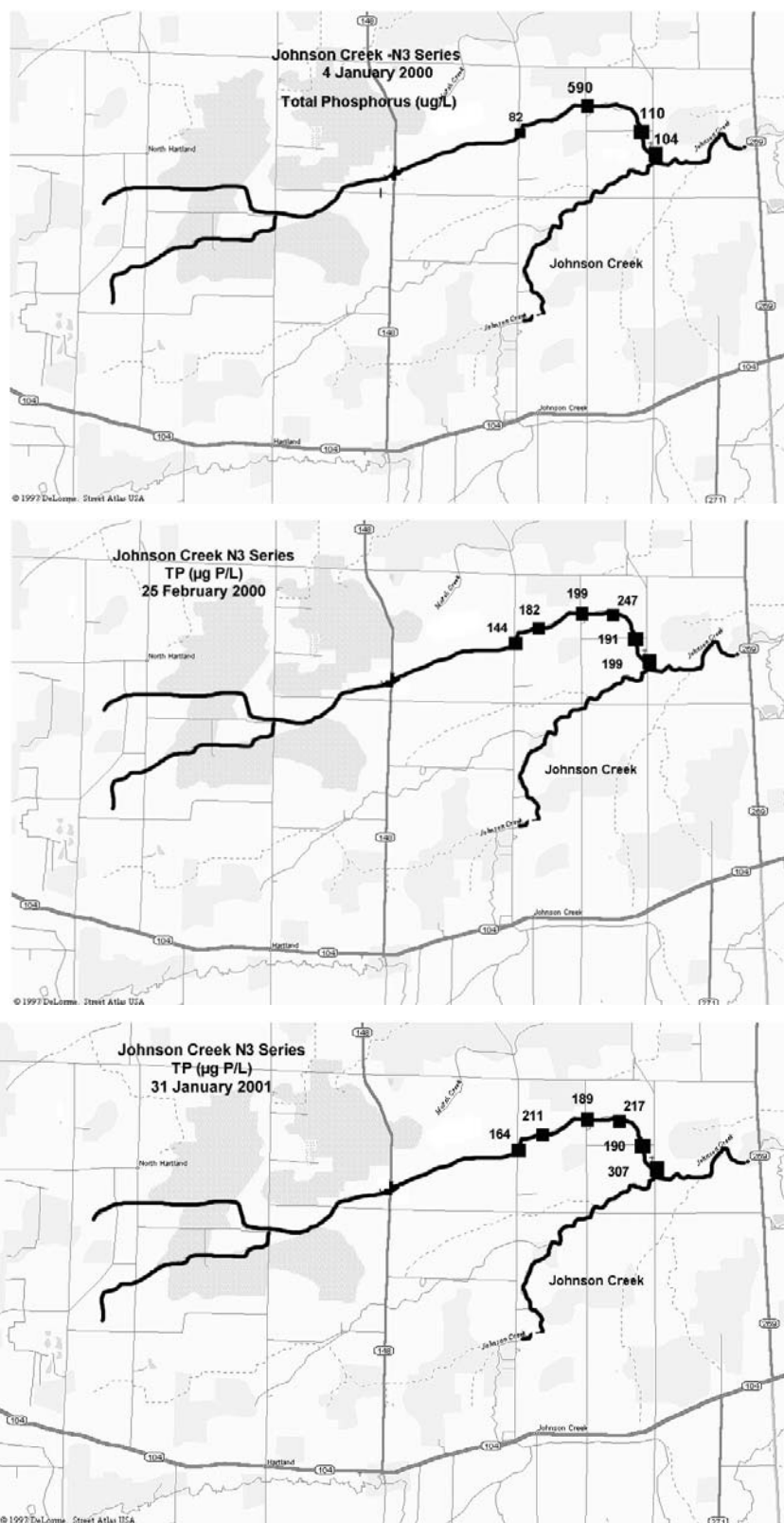


Figure 8. Total Phosphorus results for the N3 series of sites on Johnson Creek for the sampling dates 4 January 2000, 25 February 2000, and 31 January 2001.



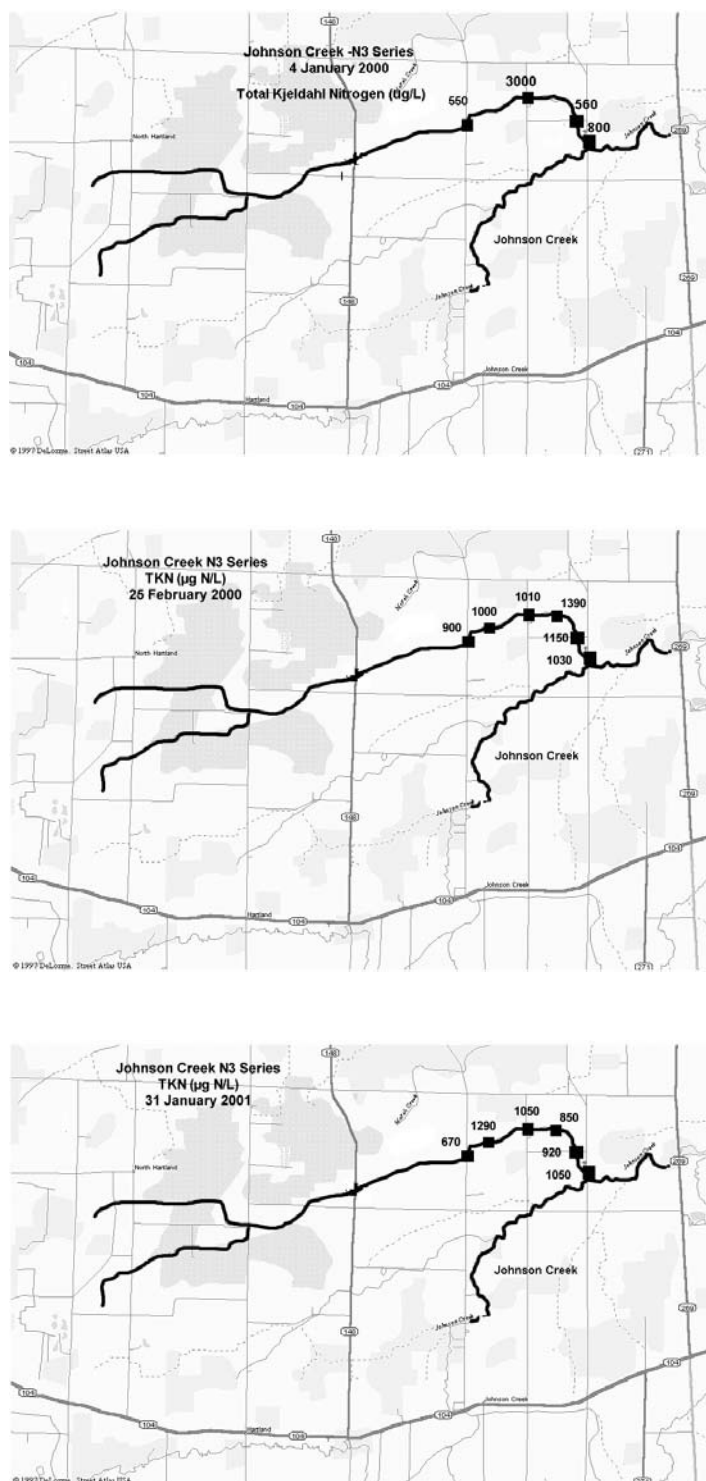


Figure 10. Total Kjeldahl Nitrogen results for the N3 series of sites on Johnson Creek for the sampling dates 4 January 2000, 25 February 2000, and 31 January 2001.

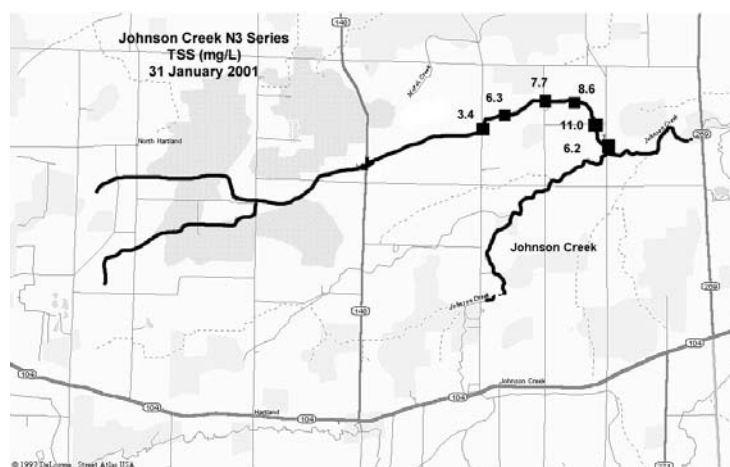
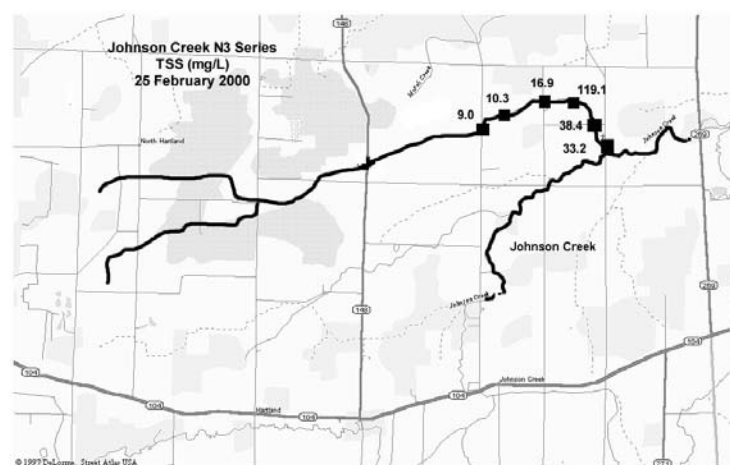
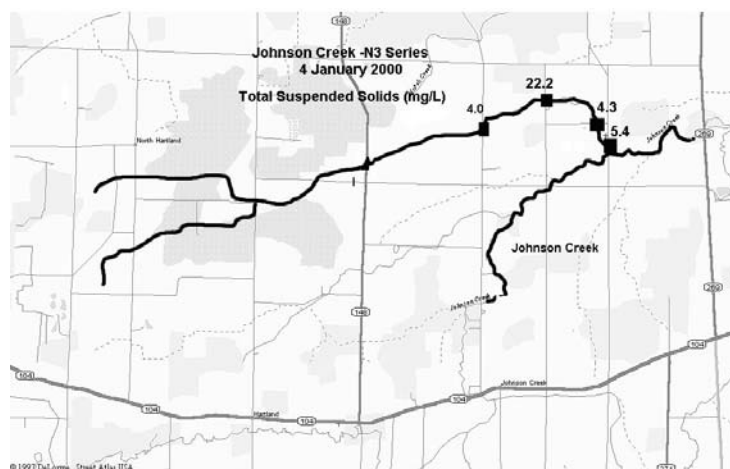


Figure 11. Total Suspended Solid results for the N3 series of sites on Johnson Creek for the sampling dates 4 January 2000, 25 February 2000, and 31 January 2001.

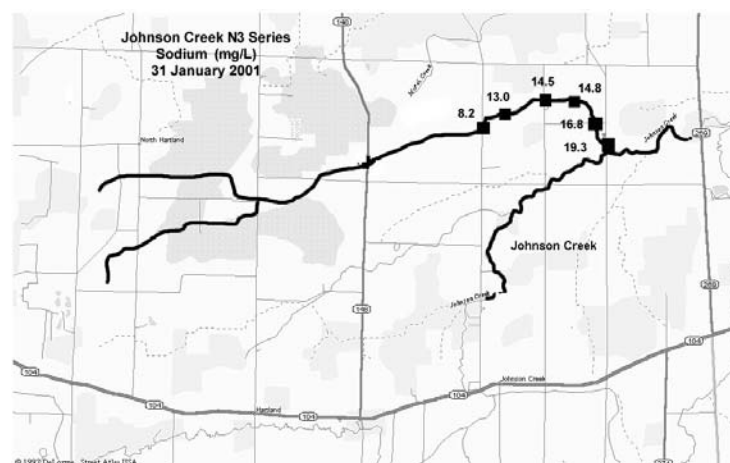
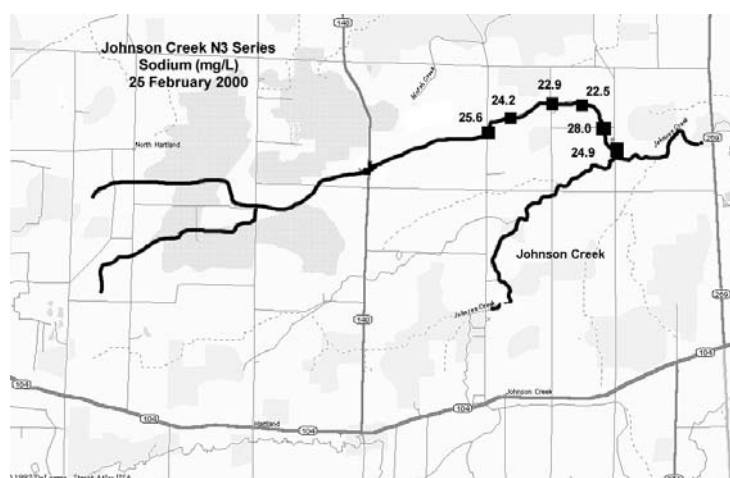
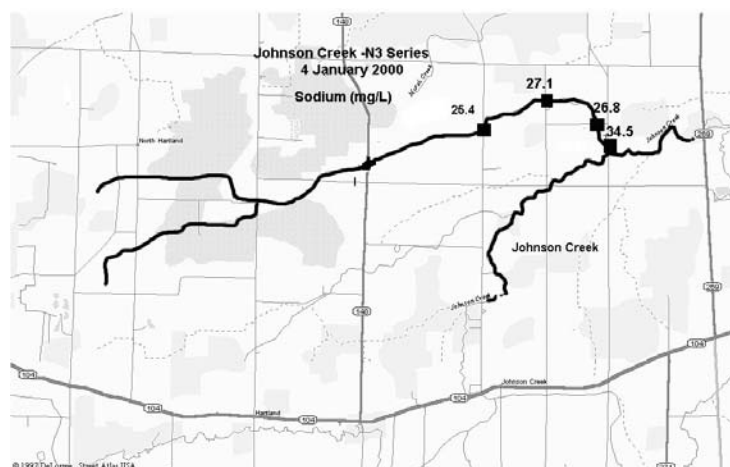


Figure 12. Sodium results for the N3 series of sites on Johnson Creek for the sampling dates 4 January 2000, 25 February 2000, and 31 January 2001.





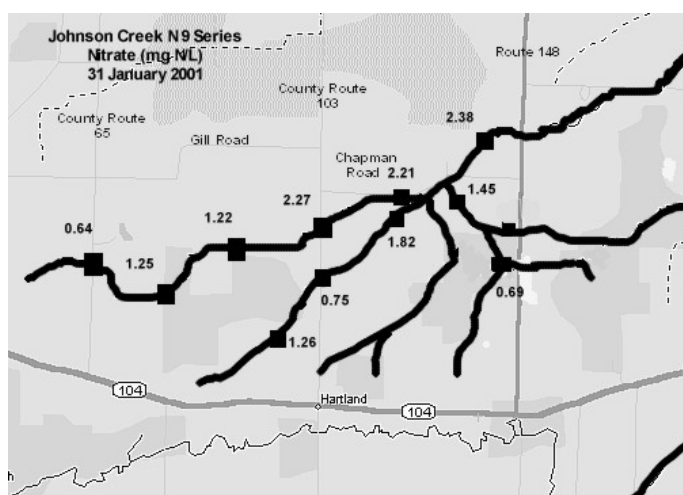
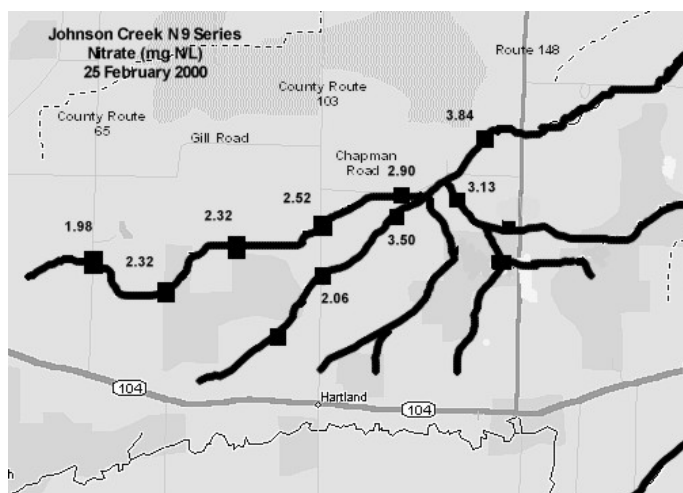
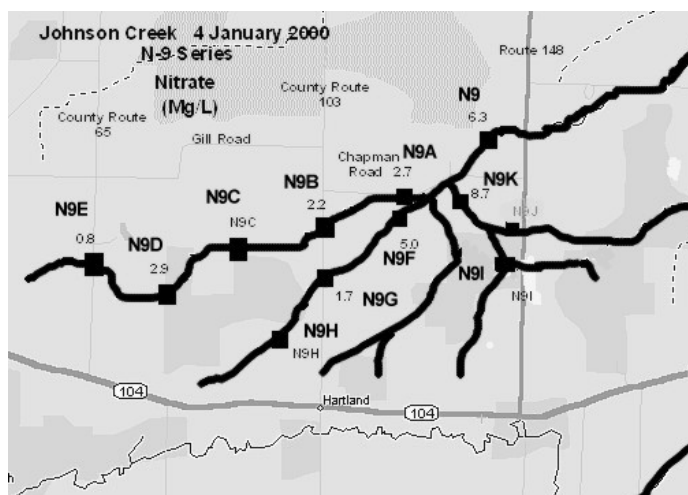


Figure 13. Nitrate results for the N9 series of sites on Johnson Creek for the sampling dates 4 January 2000, 25 February 2000, and 31 January 2001.

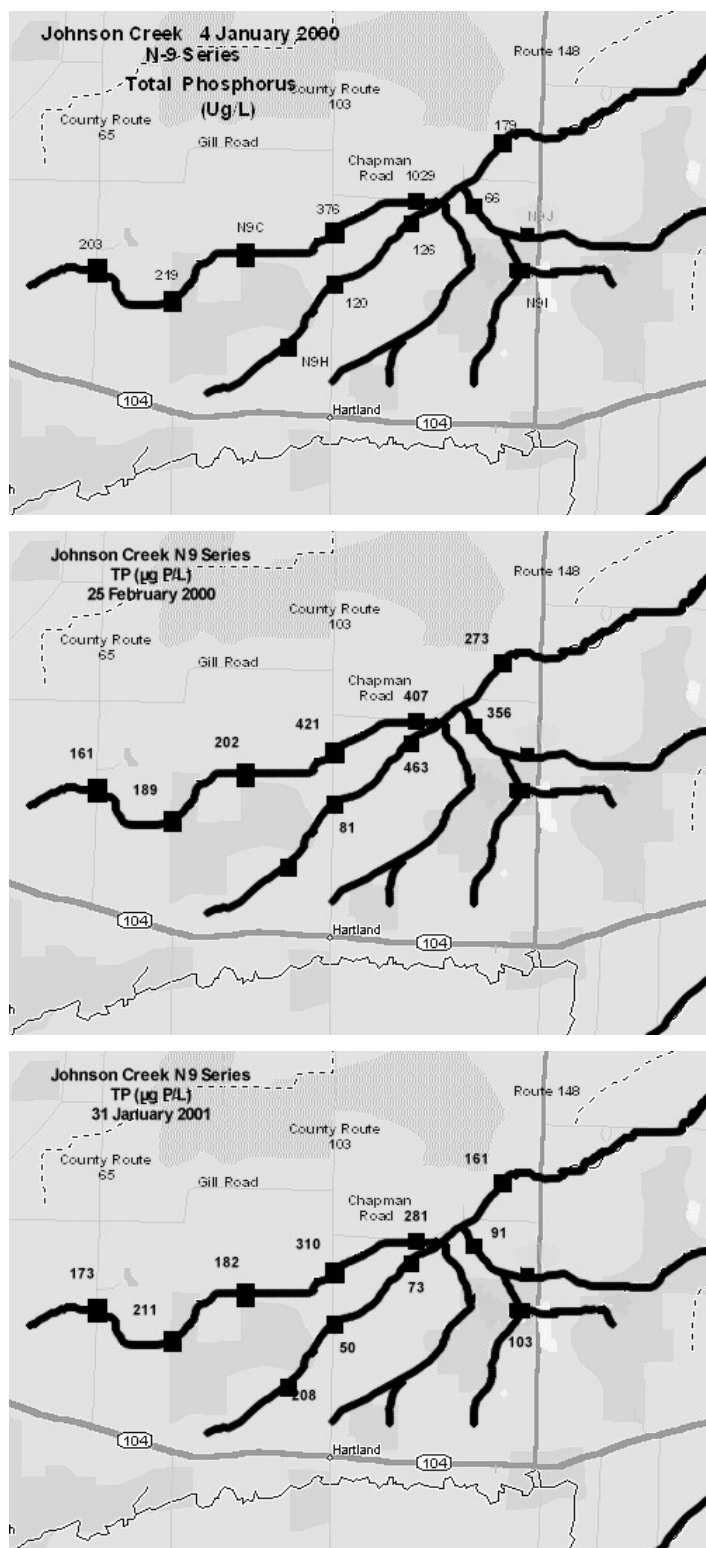


Figure 14. Total Phosphorus results for the N9 series of sites on Johnson Creek for the sampling dates 4 January 2000, 25 February 2000, and 31 January 2001.

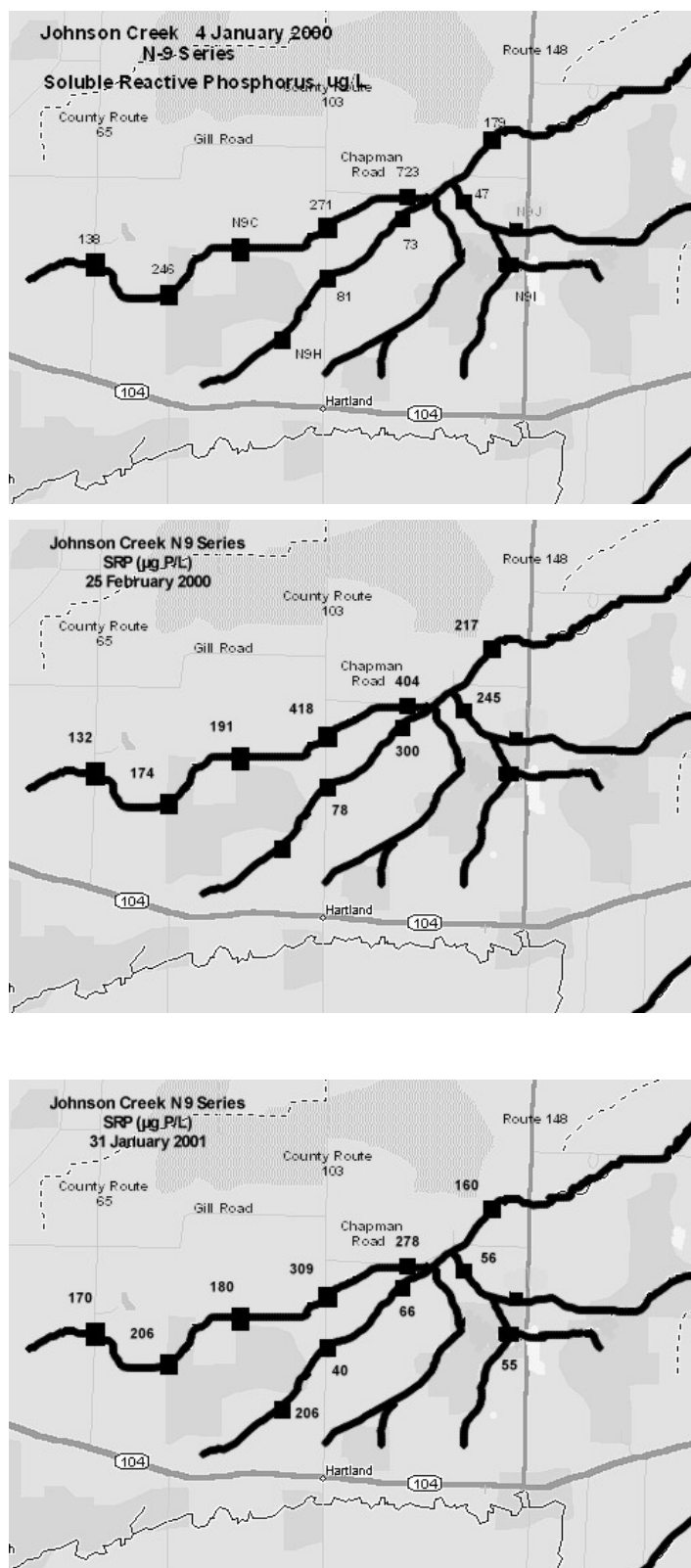


Figure 15. Soluble Reactive Phosphorus results for the N9 series on Johnson Creek for the sampling dates 4 January 2000, 25 February 2000, and 31 January 2001.

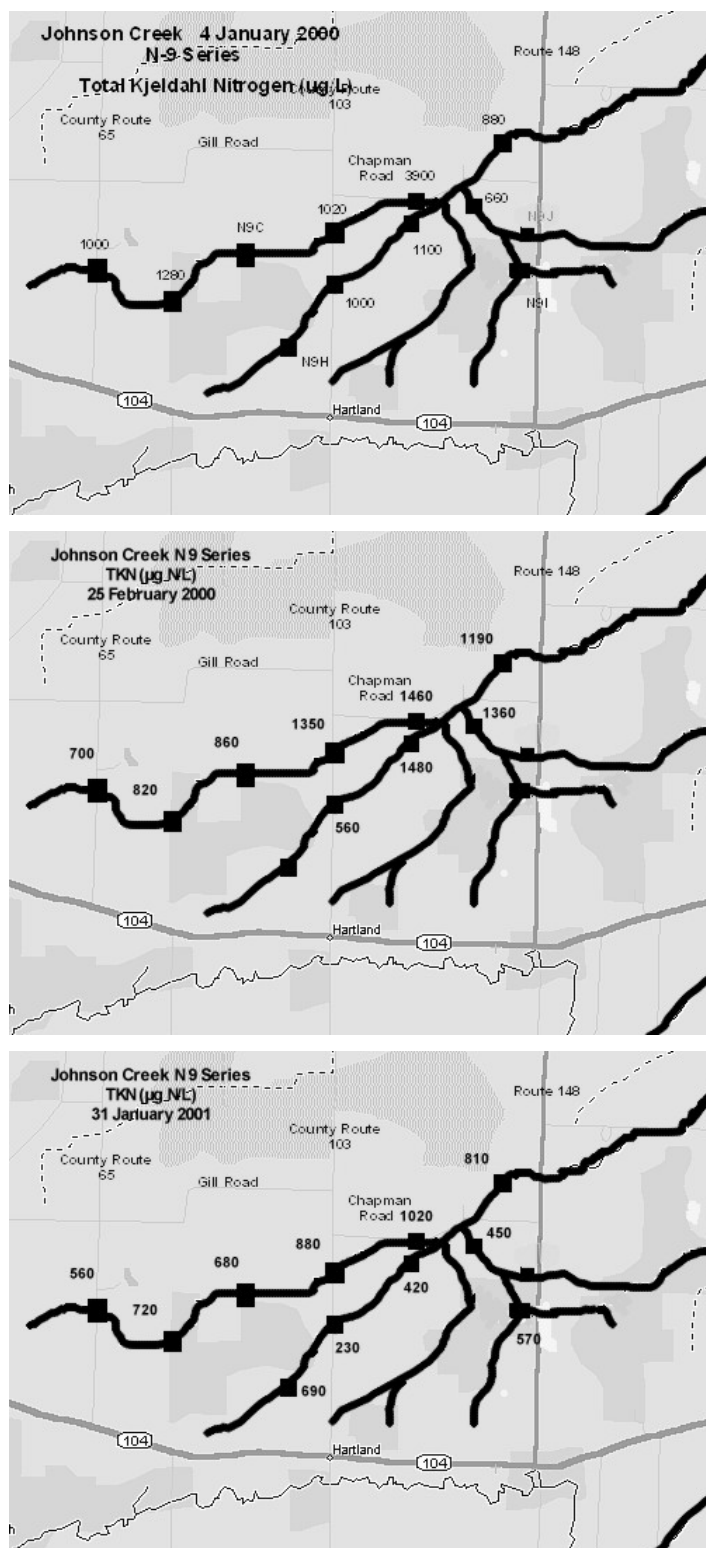


Figure 16. Total Kjeldahl Nitrogen results for the N9 series of sites on Johnson Creek for the sampling dates 4 January 2000, 25 February 2000, and 31 January 2001.

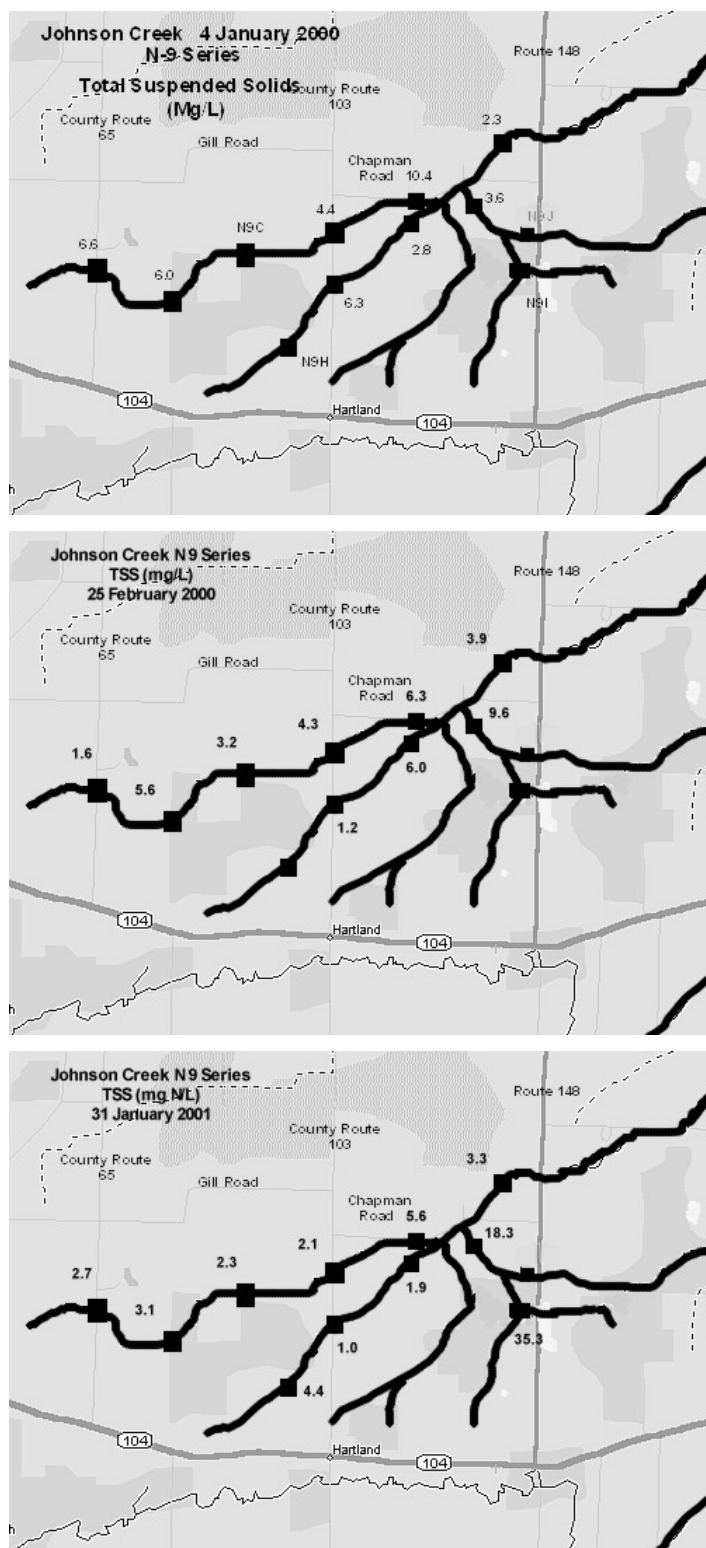


Figure 17. Total Suspended Solid results for the N9 series of sites on Johnson Creek for the sampling dates 4 January 2000, 25 February 2000, and 31 January 2001.

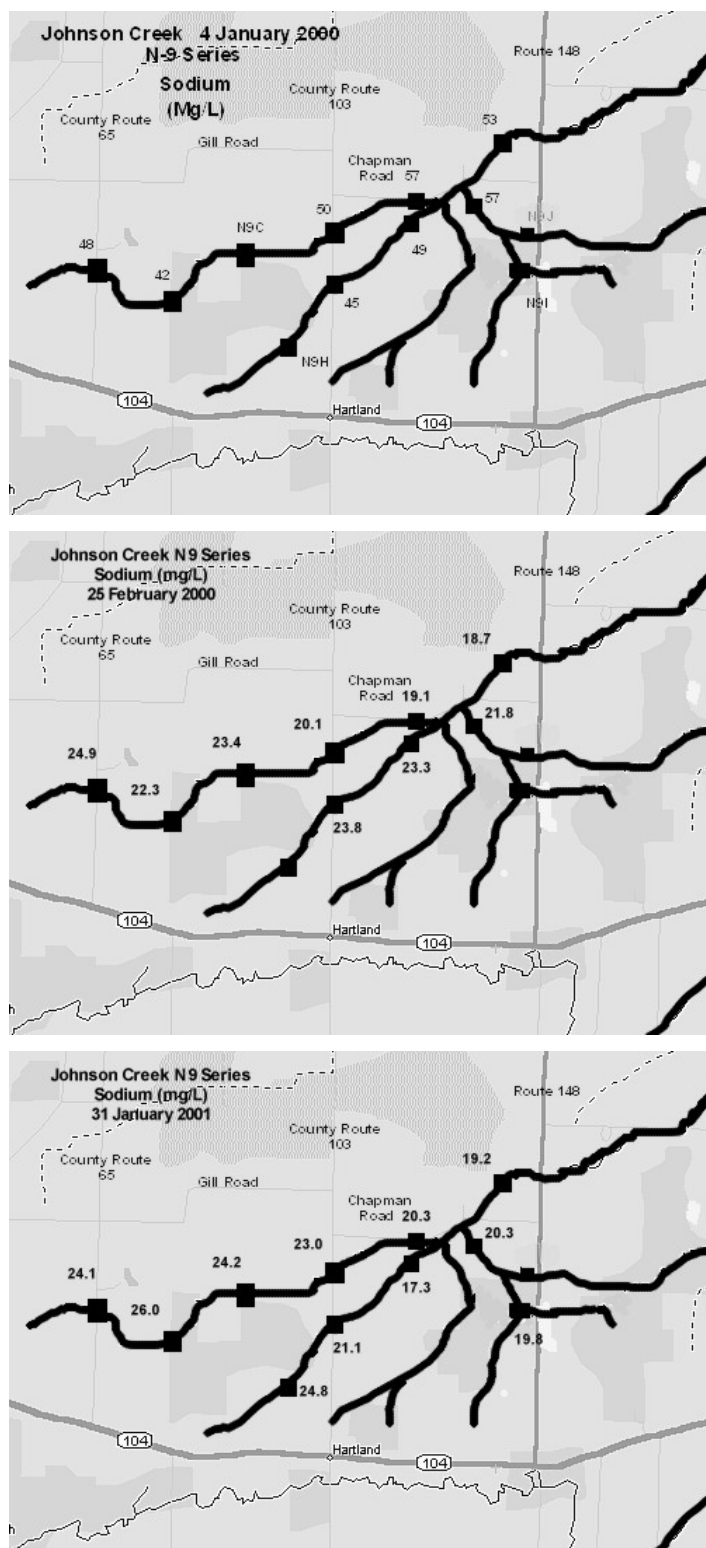


Figure 18. Sodium results for the N9 series of sites on Johnson Creek for the sampling dates 4 January 2000, 25 February 2000, and 31 January 2001.

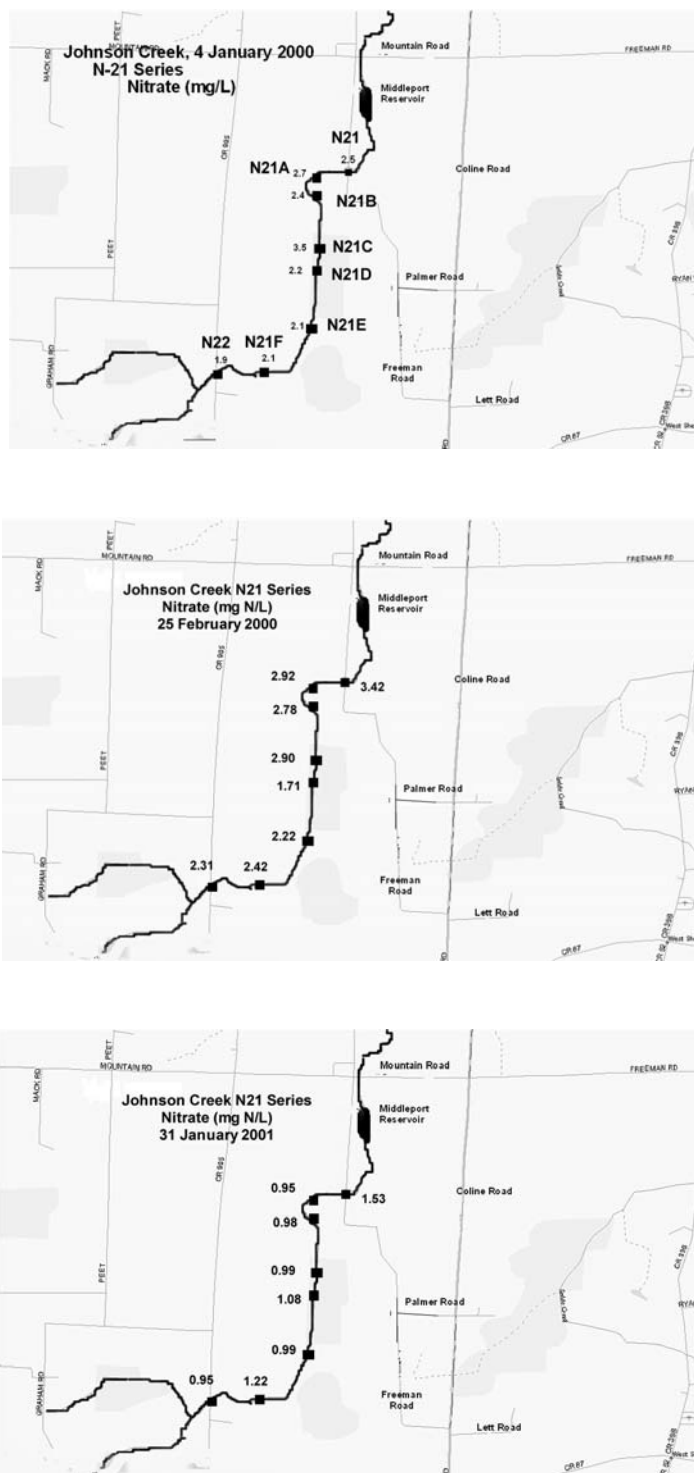


Figure 19. Nitrate results for the N21 series of sites on Johnson Creek for the sampling dates 4 January 2000, 25 February 2000, and 31 January 2001.

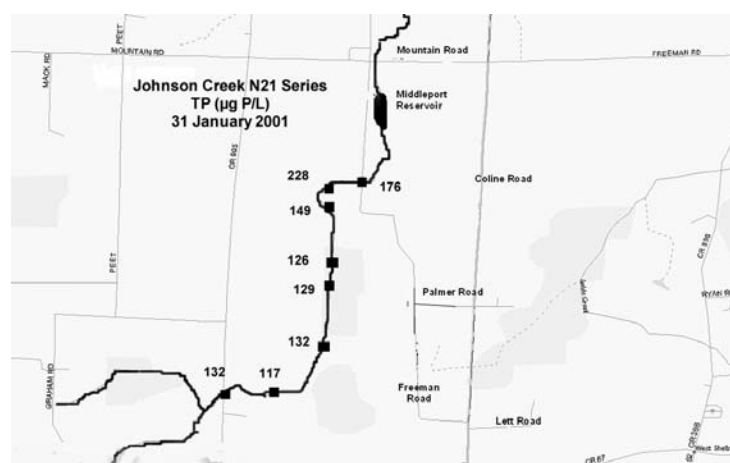
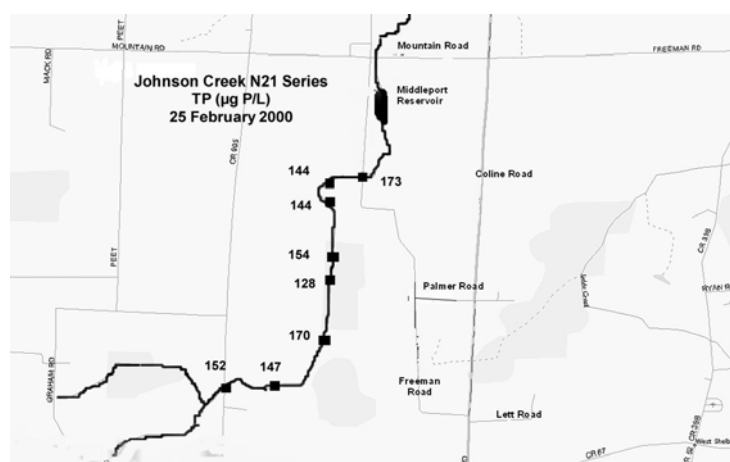
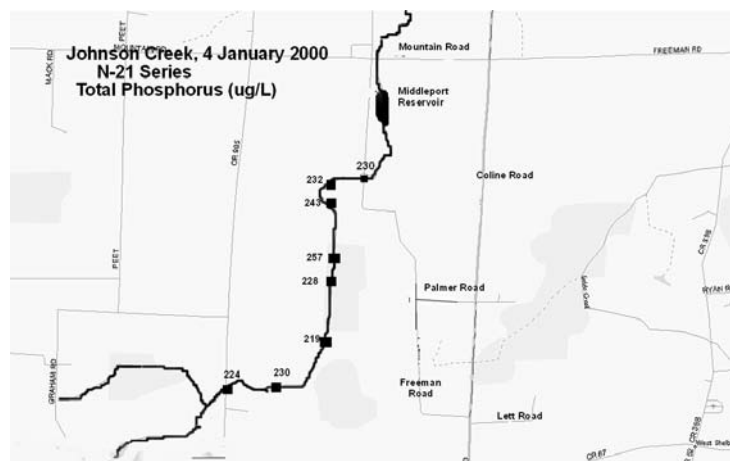


Figure 20. Total Phosphorus results for the N21 series of sites on Johnson Creek for the sampling dates 4 January 2000, 25 February 2000, and 31 January 2001.



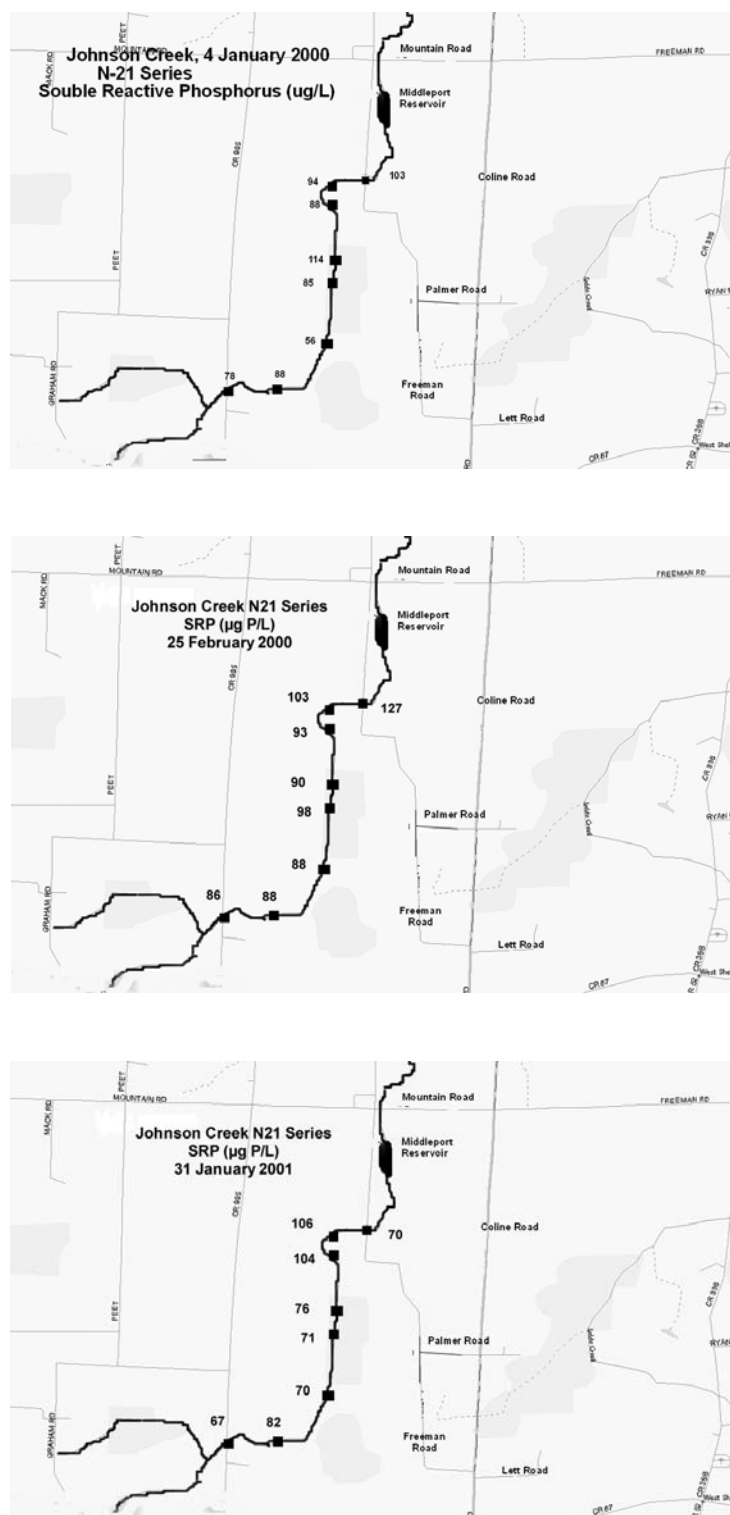


Figure 21. Soluble Reactive Phosphorus results for the N21 series of sites on Johnson Creek for the sampling dates 4 January 2000, 25 February 2000, and 31 January 2001.

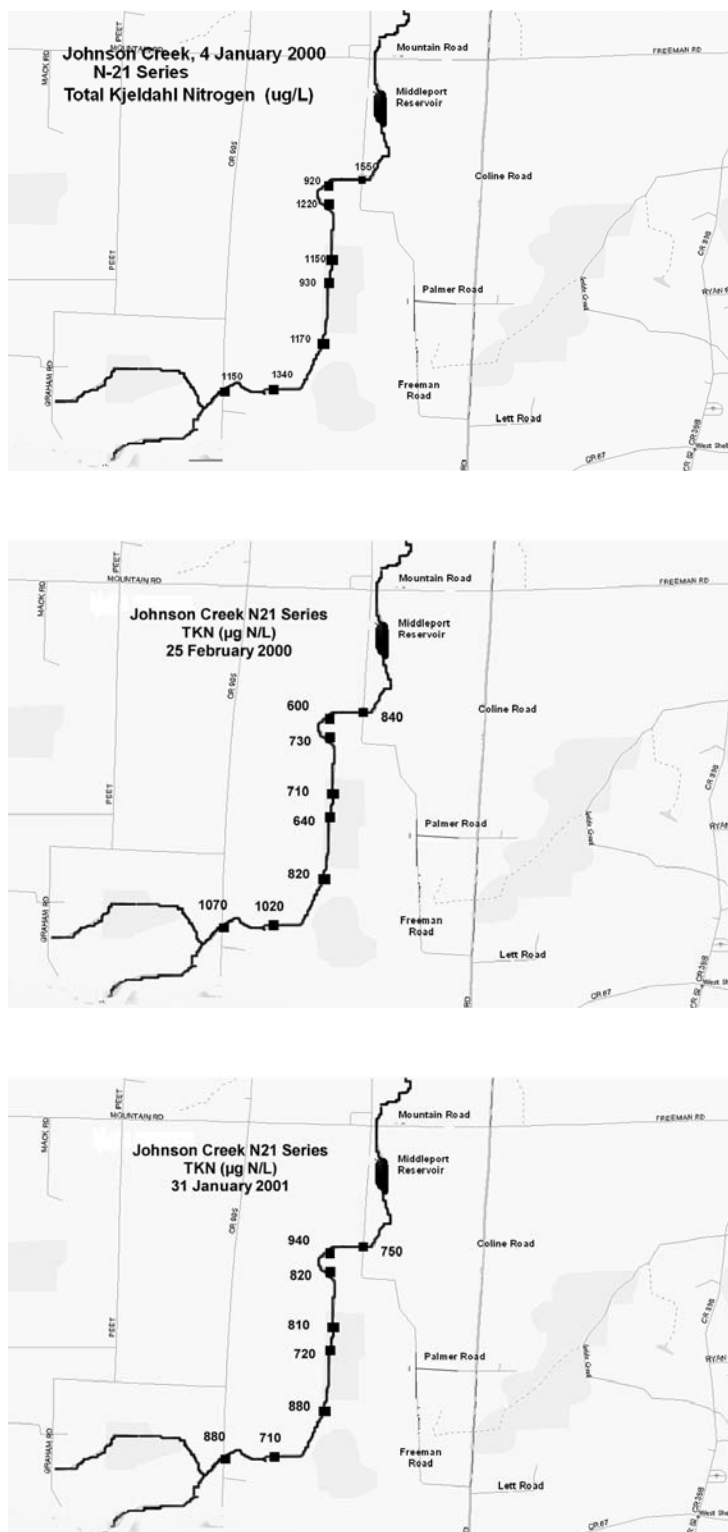


Figure 22. Total Kjeldahl Nitrogen results for the N21 series of sites on Johnson Creek for the sampling dates 4 January 2000, 25 February 2000, and 31 January 2001.

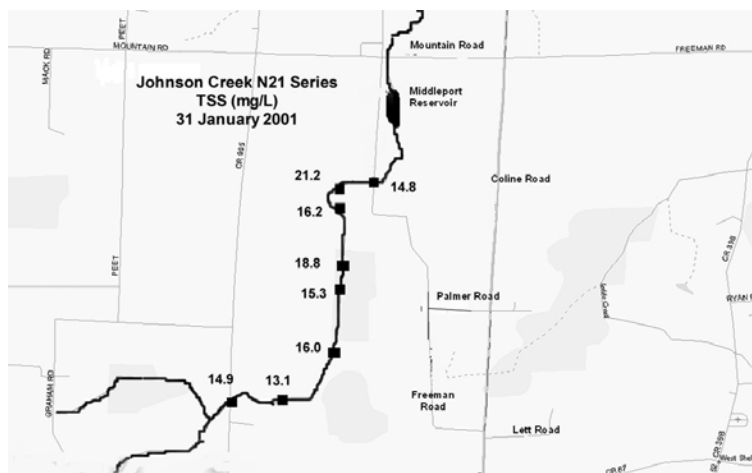
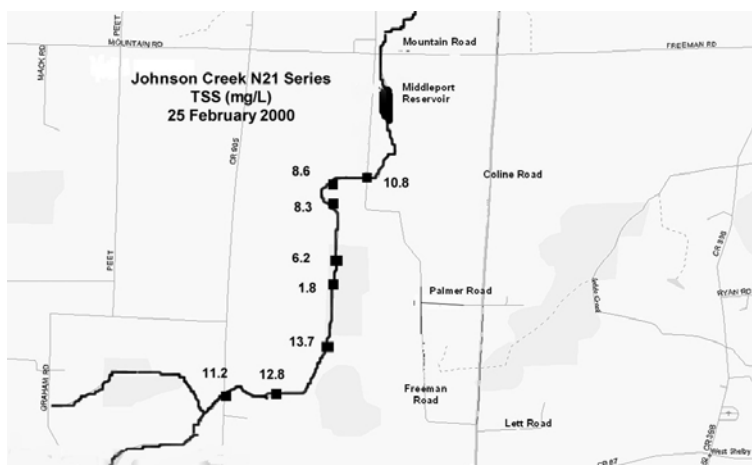
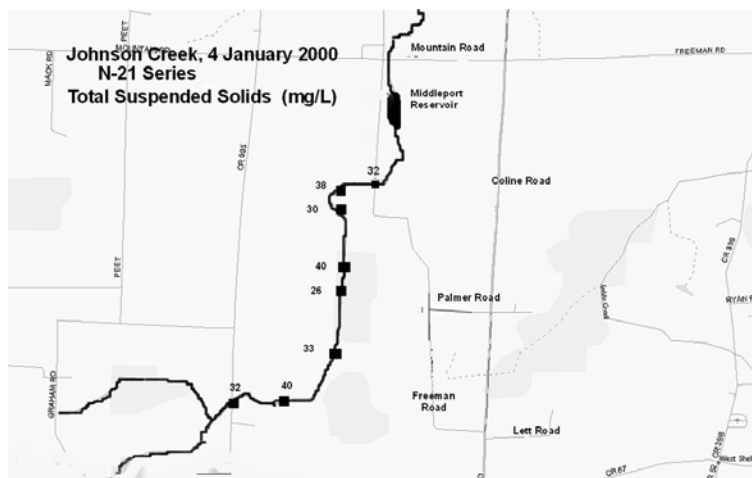


Figure 23. Total Suspended Solid results for the N21 series of sites on Johnson Creek for the sampling dates 4 January 2000, 25 February 2000, and 31 January 2001.

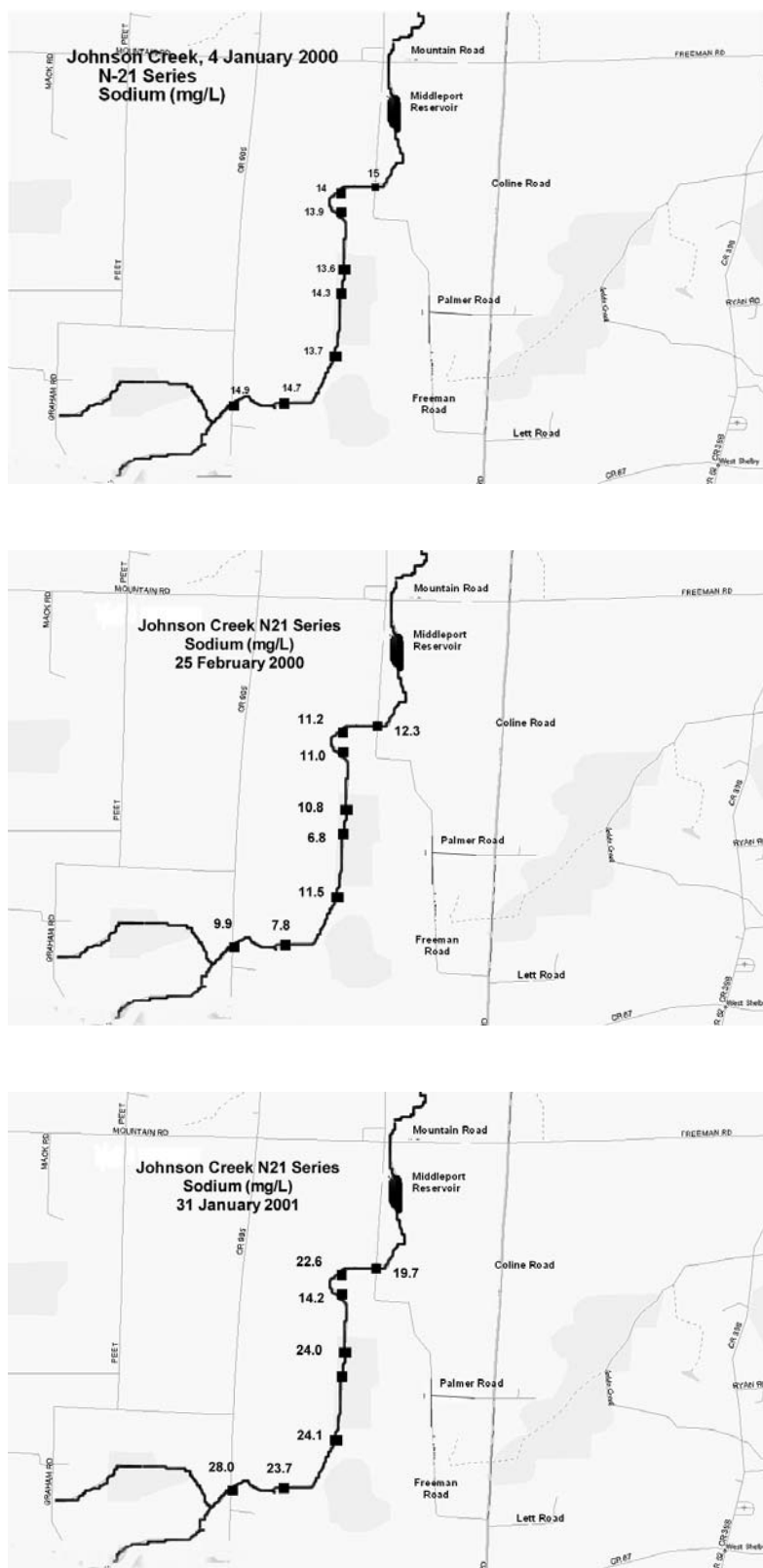


Figure 24. Sodium results for the N21 series of sites on Johnson Creek for the sampling dates 4 January 2000, 25 February 2000, and 31 January 2001.